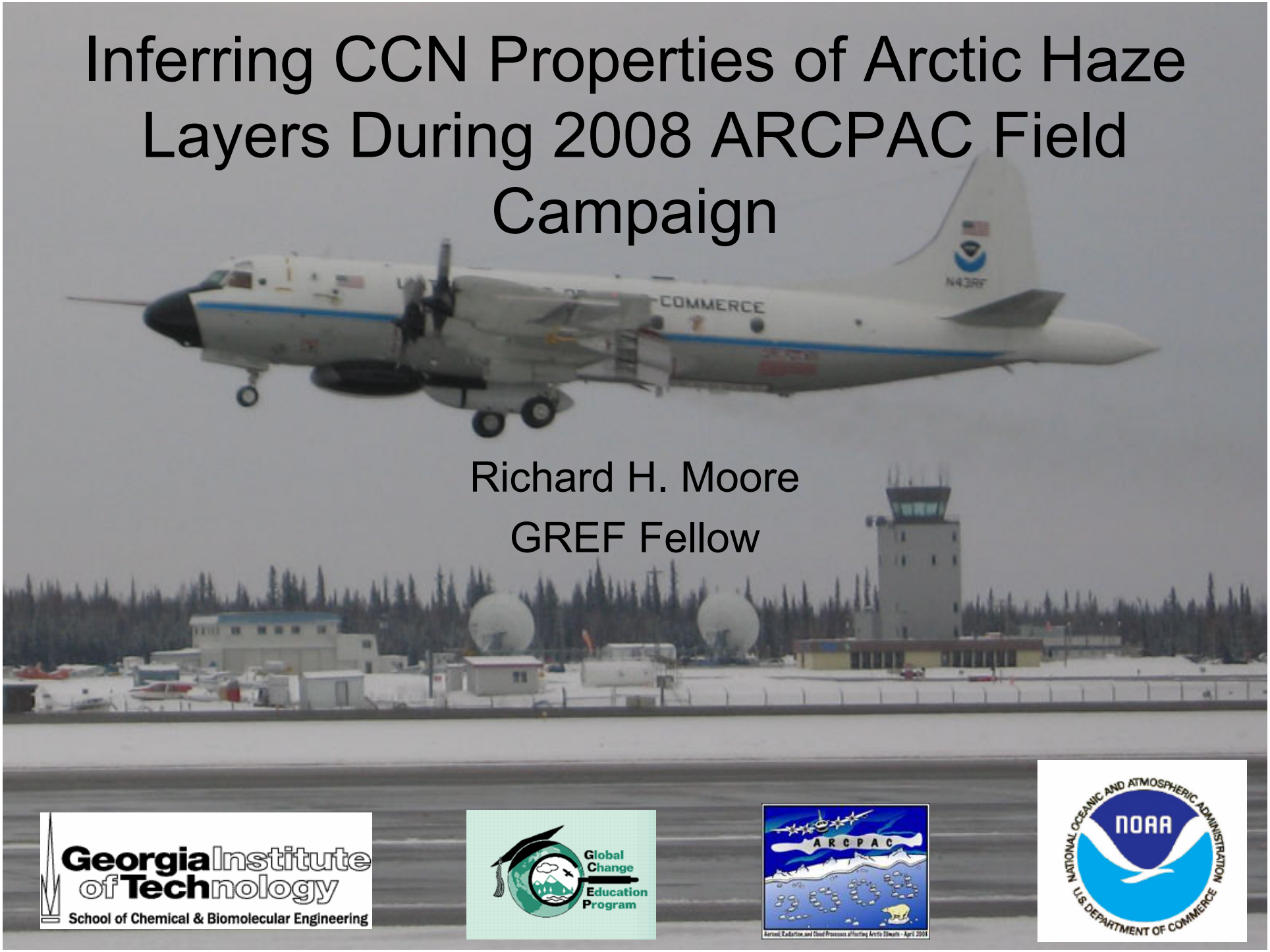
Inferring CCN Properties of Arctic Haze Layers During 2008 ARCPAC Field Campaign



Richard H. Moore

GREF Fellow

Georgia Institute of Technology
School of Chemical & Biomolecular Engineering

Global Change Education Program

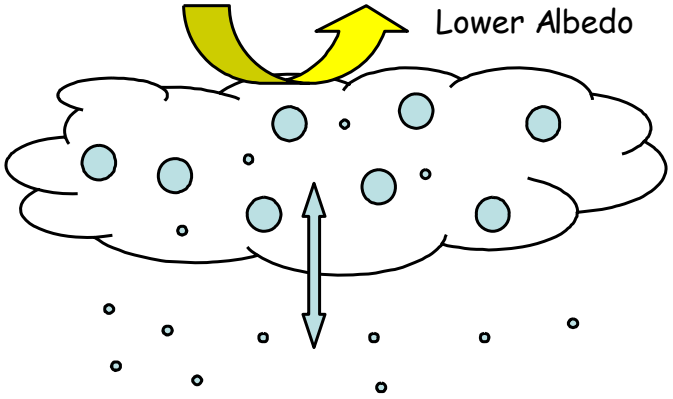
ARCPAC

NOAA
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

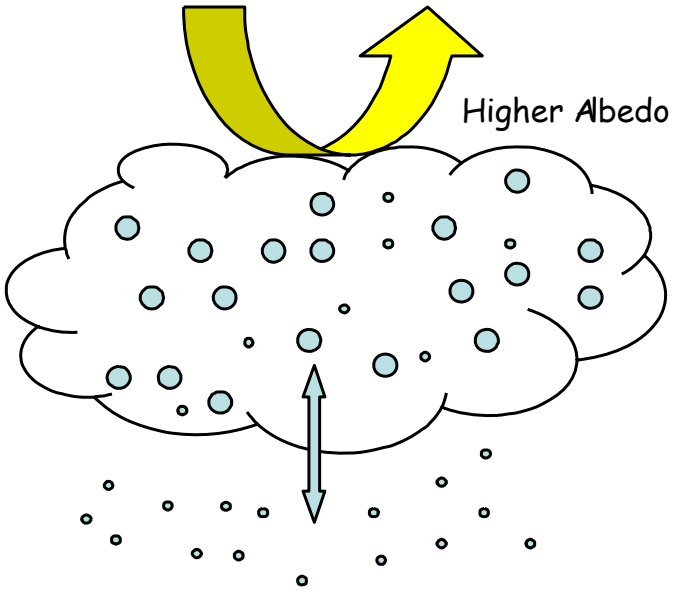
Overview

- Motivation: Aerosols, Clouds, Climate
- Cloud Droplet Formation and Growth
- CCN Measurement & Characterization
  - CCN Closure
    - Organic Properties
    - Surface Tension Effects
    - Mixing State
  - Droplet Growth Kinetics
- 2008 ARCPAC Field Campaign
- Vertical Profiles of Haze

Motivation: Aerosol Indirect Effects



Clean Environment
(fewer aerosols)



Polluted Environment
(more aerosols)

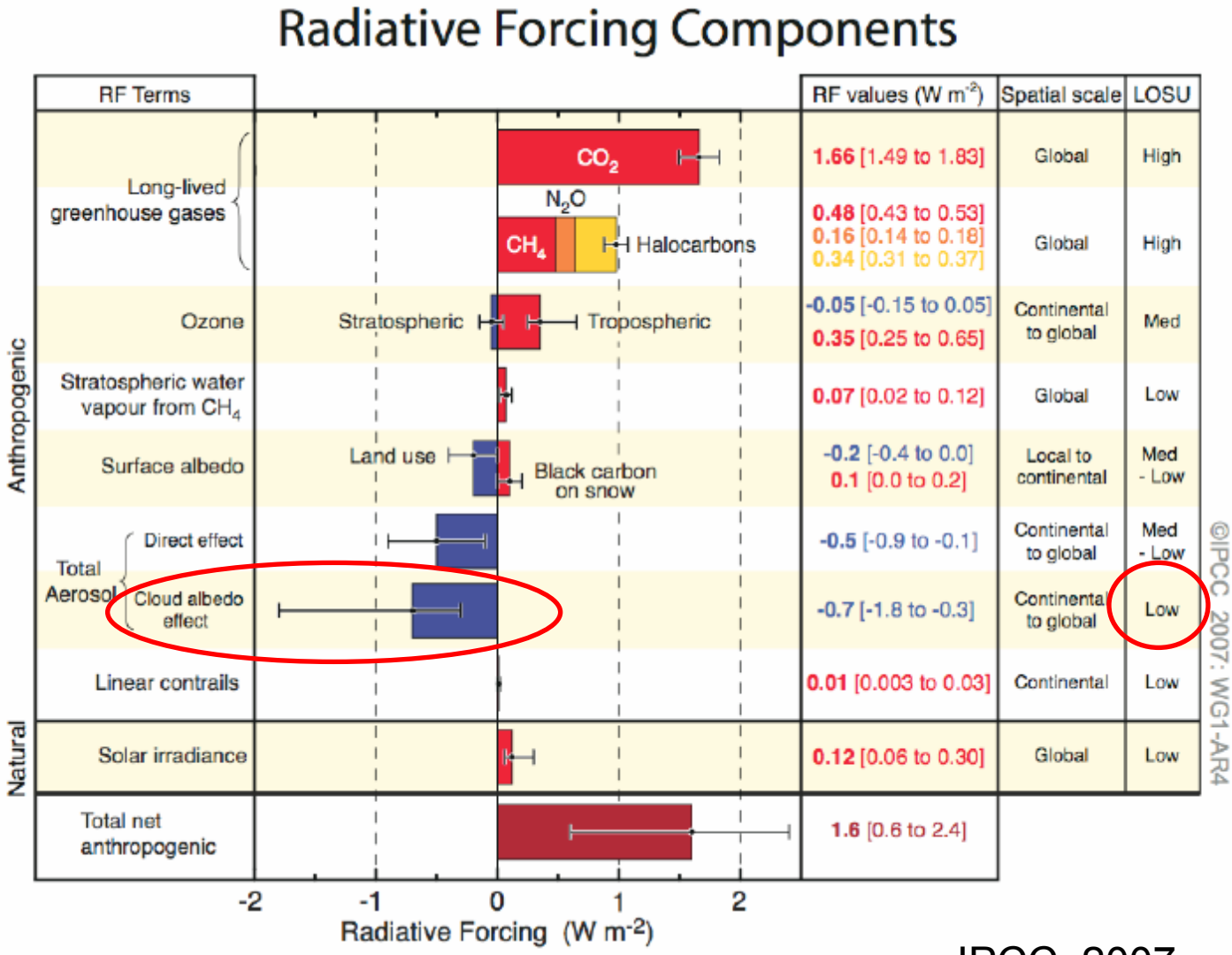
1st Indirect Effect: Polluted clouds will have smaller and more numerous droplets, which makes the cloud denser and able to reflect more incoming radiation

2nd Indirect Effect: Smaller droplets increase cloud lifetime by suppressing precipitation

Credit: A. Asa-Awuku

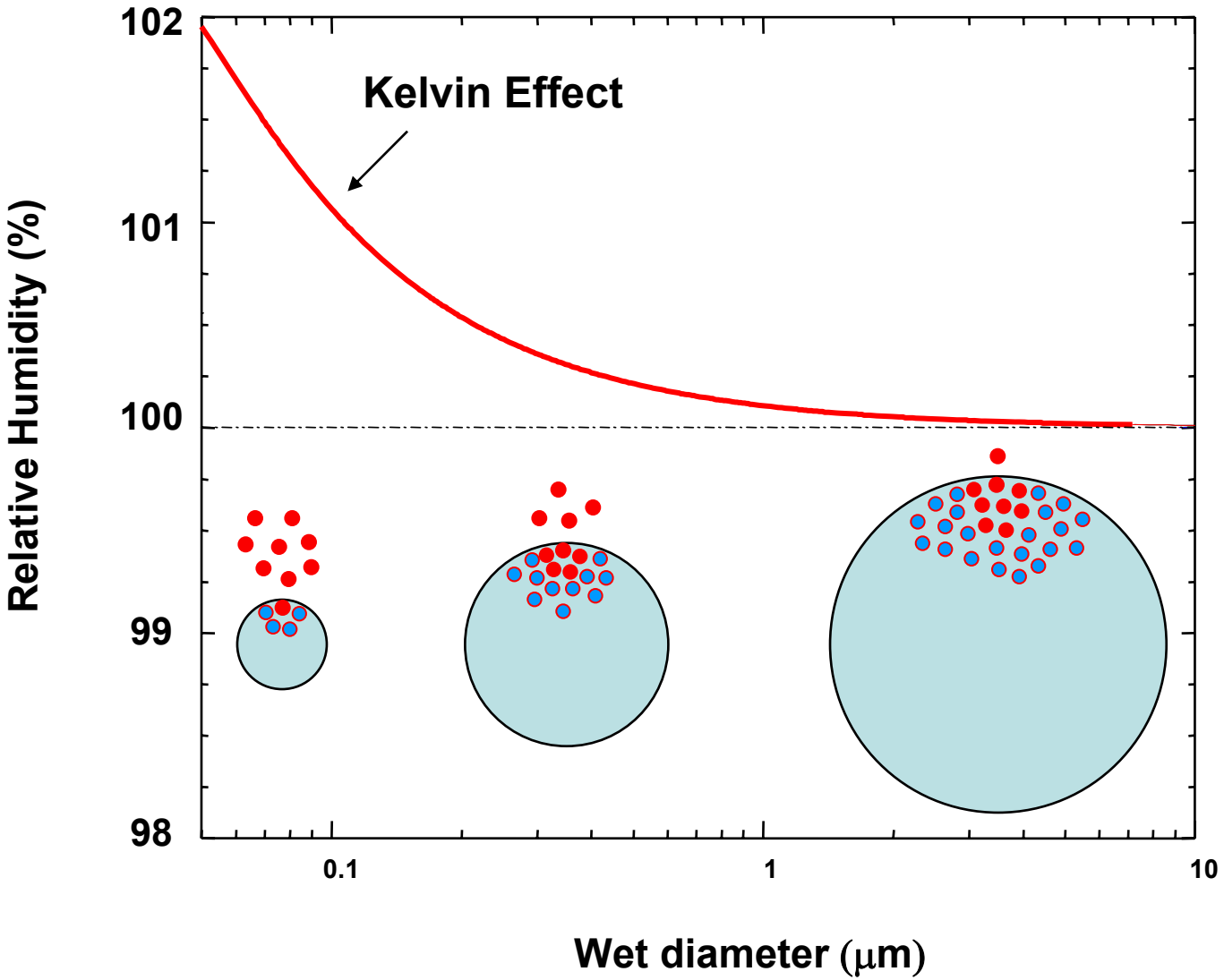
Motivation: Aerosol Indirect Effects

- Can compare present-day energy balance to preindustrial (1750 AD).
- Impacts of greenhouse gases are well understood
- Impacts of aerosols are poorly understood



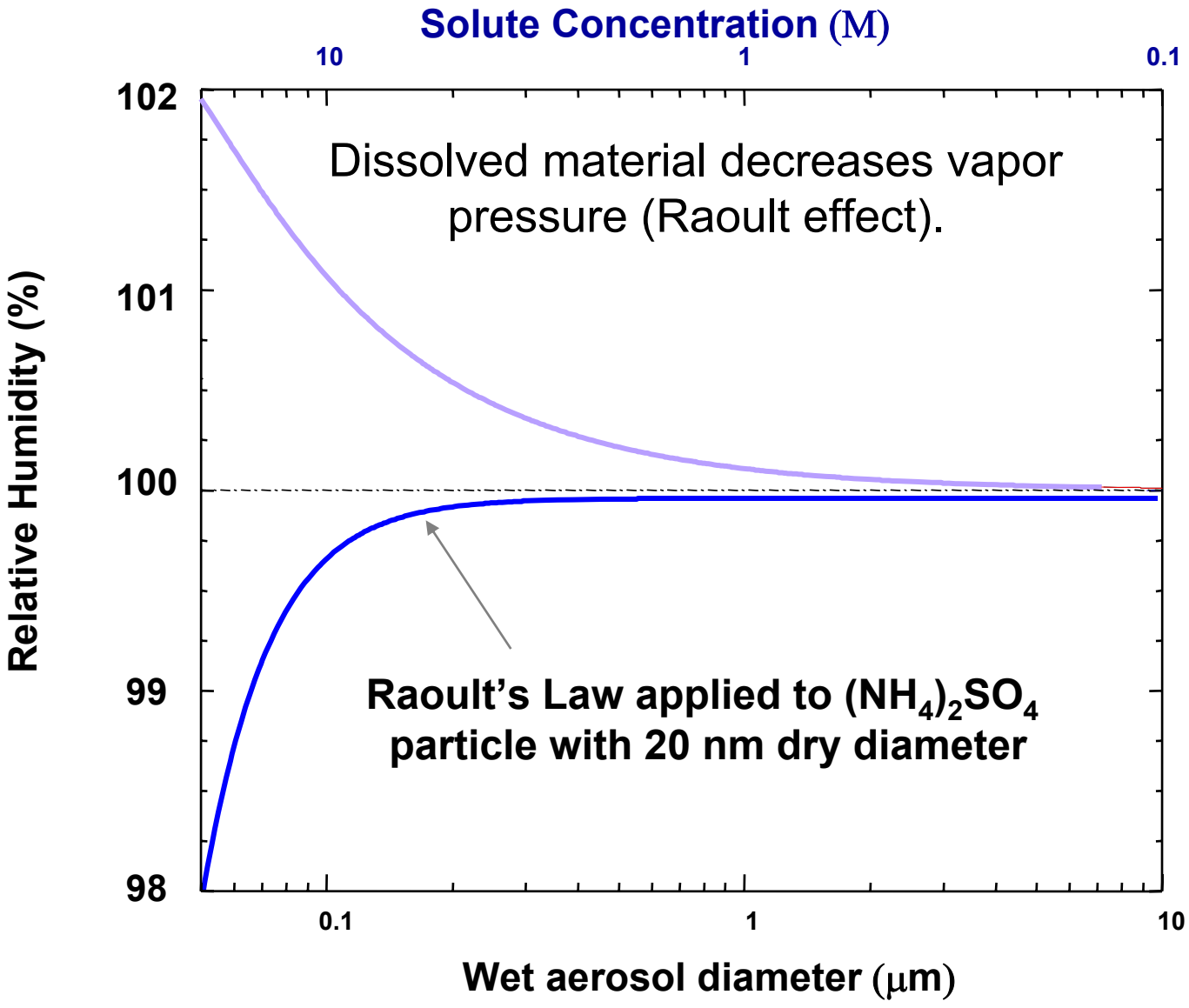
IPCC, 2007

How Do Aerosols Form Droplets?



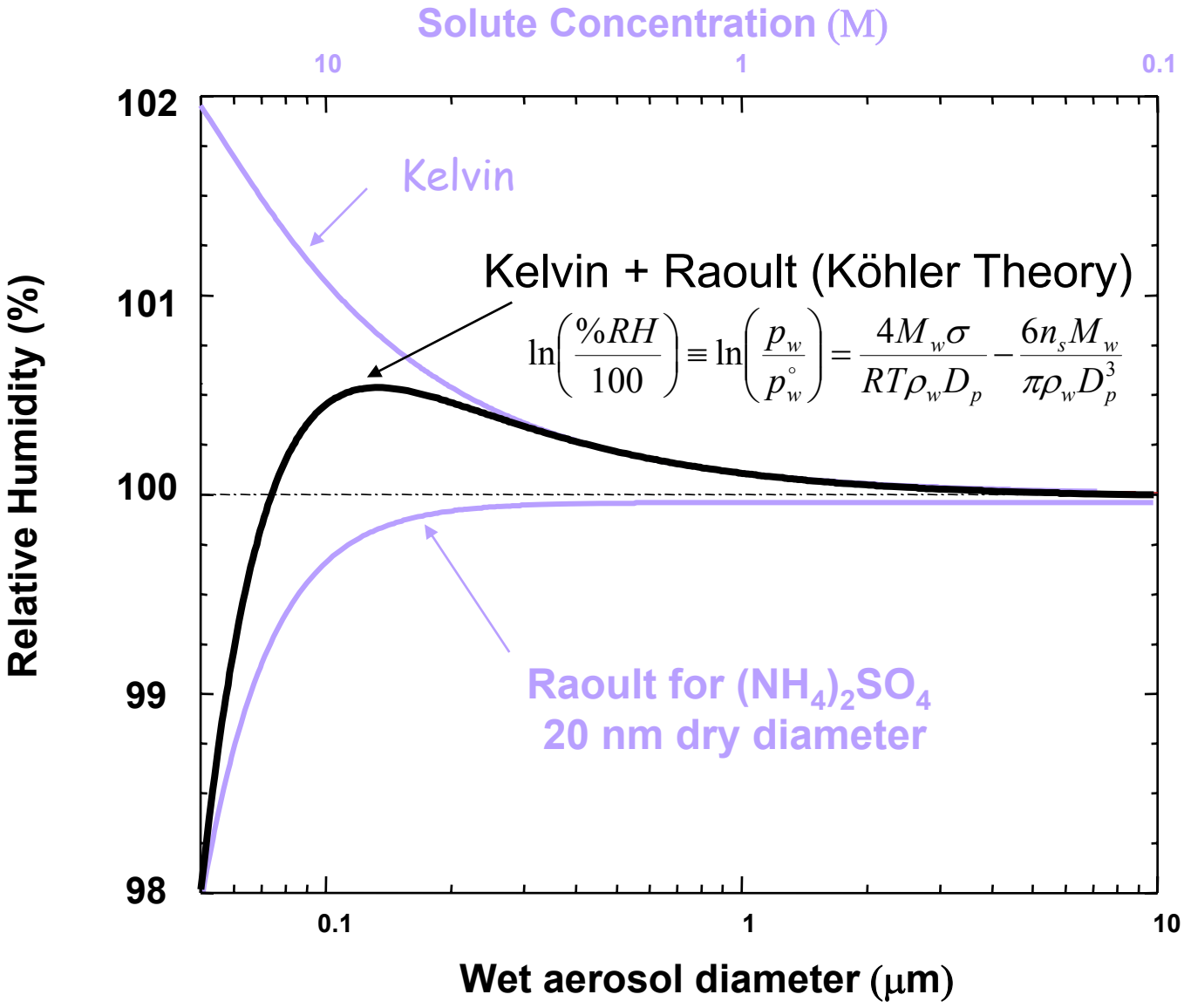
Credit: A. Nenes

How Do Aerosols Form Droplets?



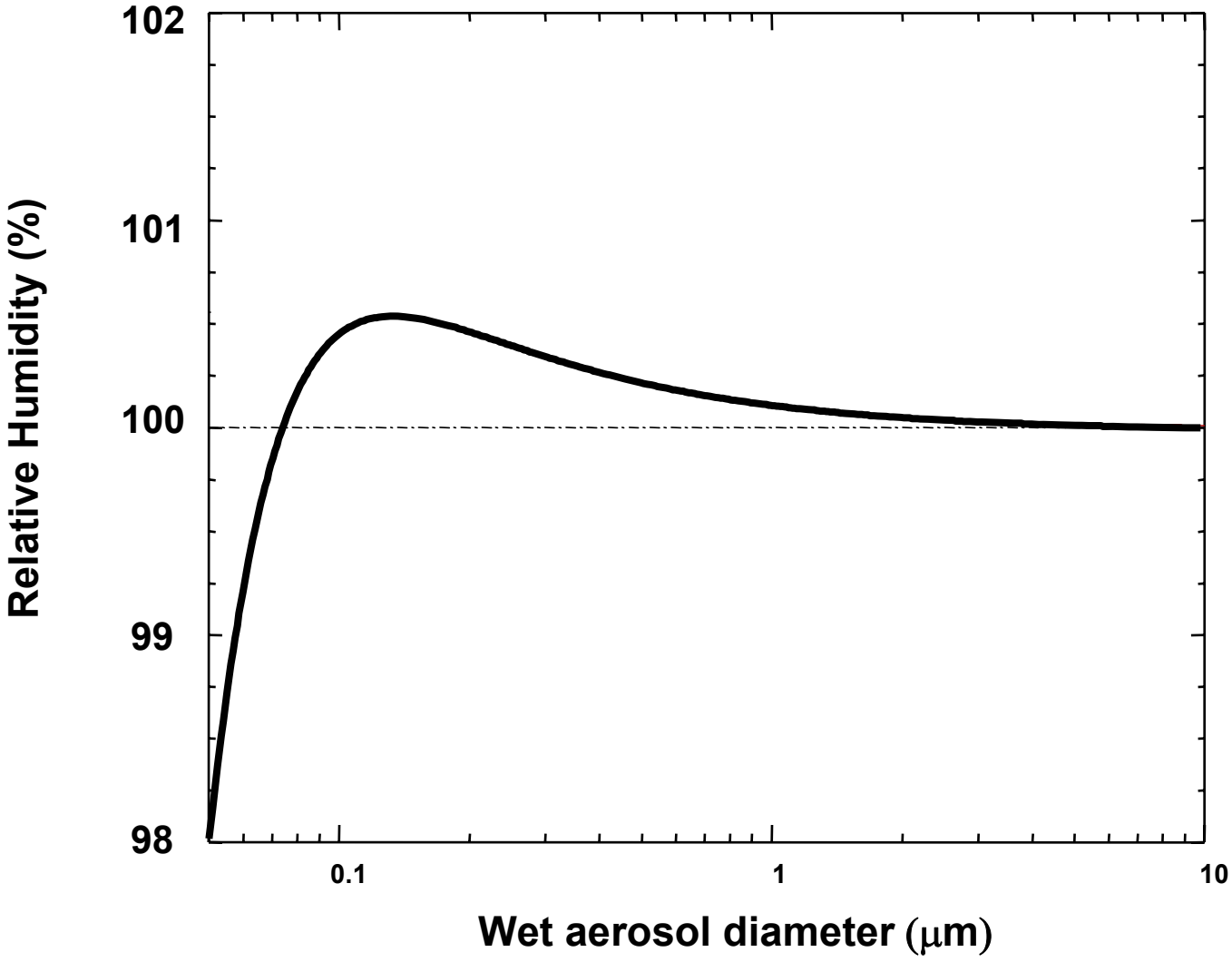
Credit: A. Nenes

How Do Aerosols Form Droplets?

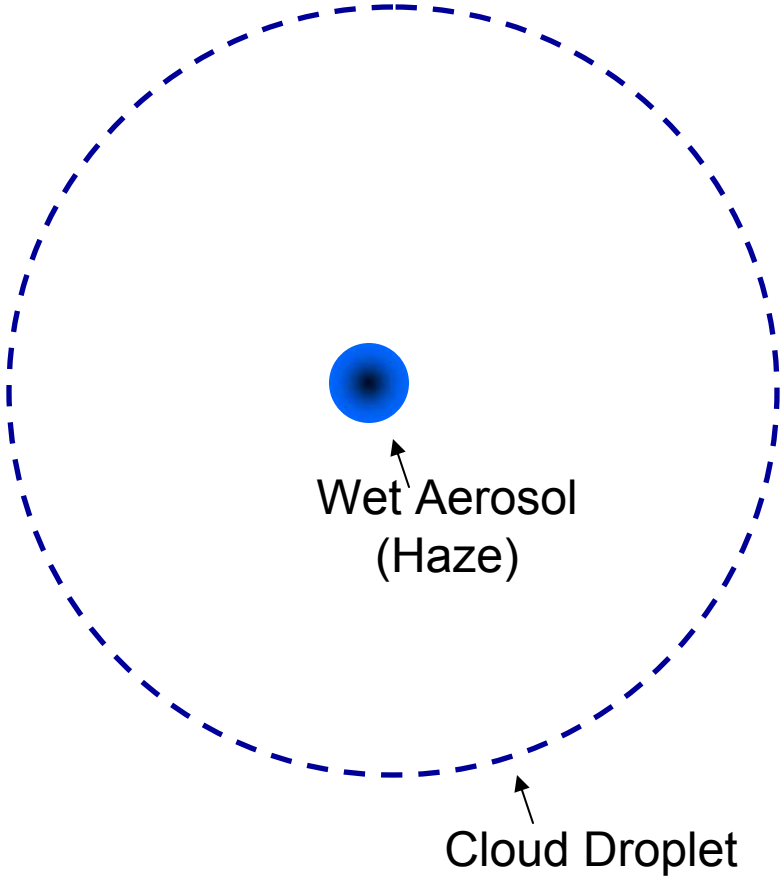


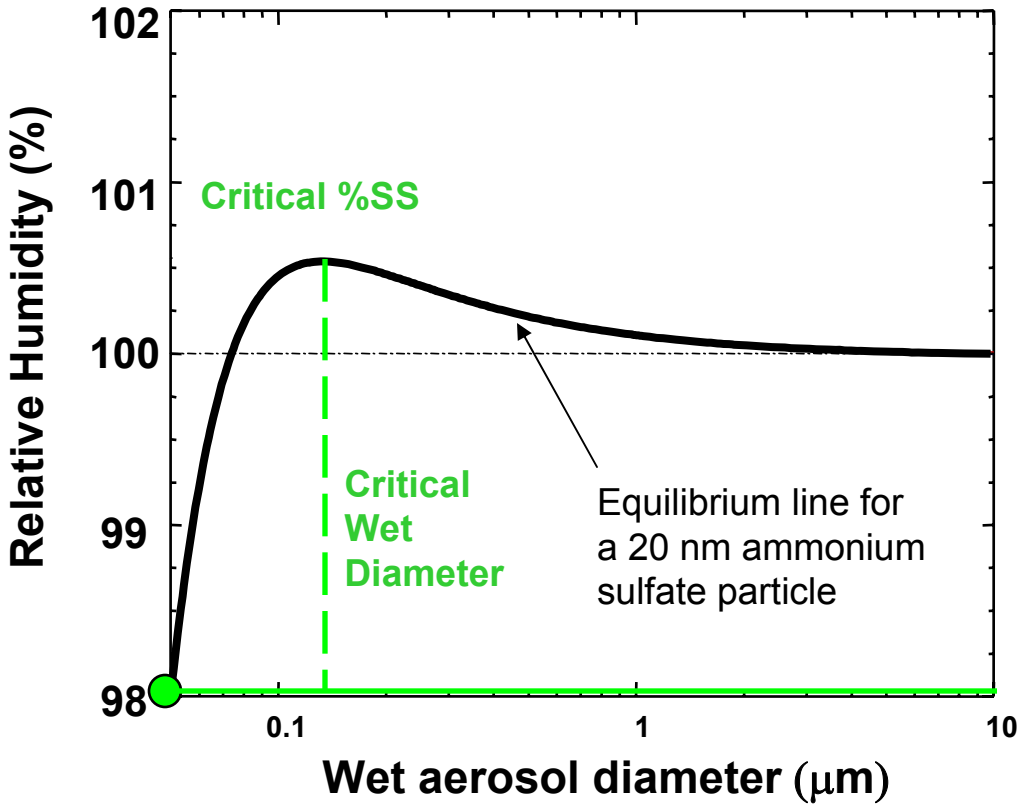
Credit: A. Nenes

How Do Aerosols Form Droplets?



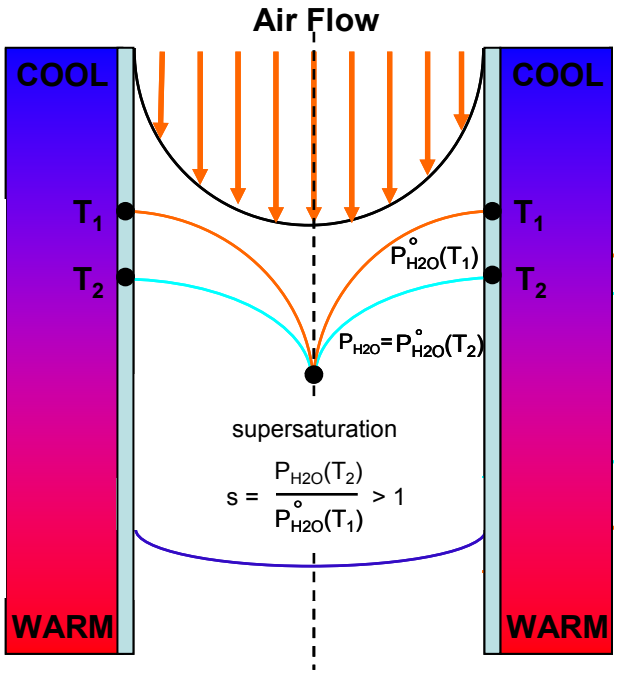
How Do Aerosols Form Droplets?



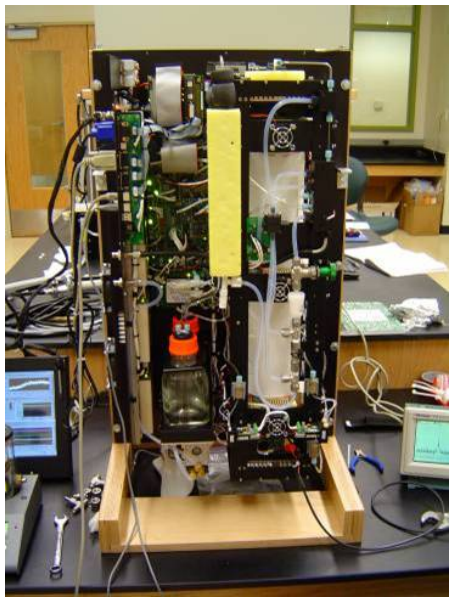


CCN = f (Size, Chemical Composition)

Measuring CCN Activation and Growth with the DMT Continuous-Flow Streamwise Thermal-Gradient CCN Counter



- Expose aerosol to a fixed water vapor supersaturation for a fixed amount of time
- Measure CCN Concentration and Final Droplet Size.



CCN Closure: Comparing Observations with Predictions from Köhler Theory

Measured **composition** from AMS &
Assumptions: Mixing State, Surface Tension, Organic Properties

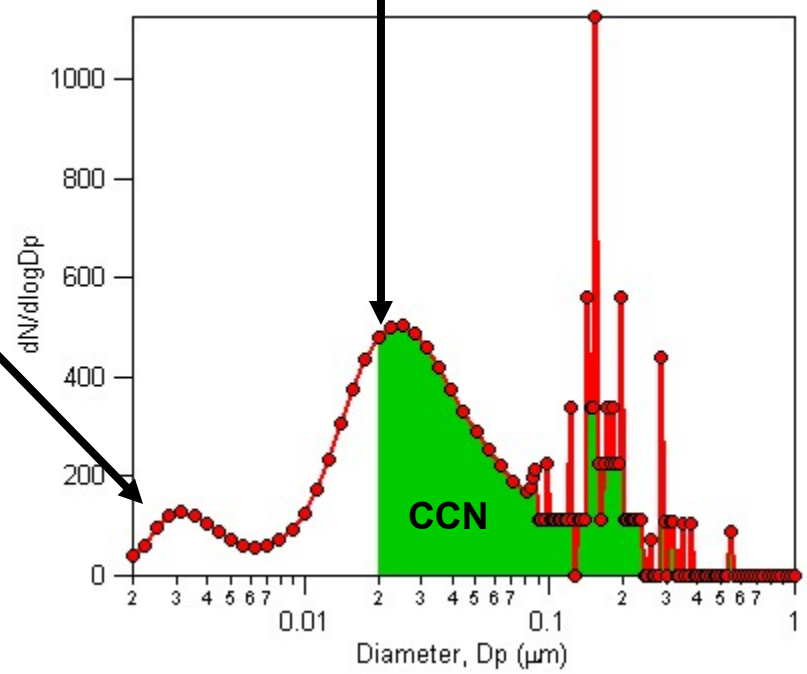
+

Measured **size distribution** from UHSAS, CPCs

=

Predicted CCN Concentration

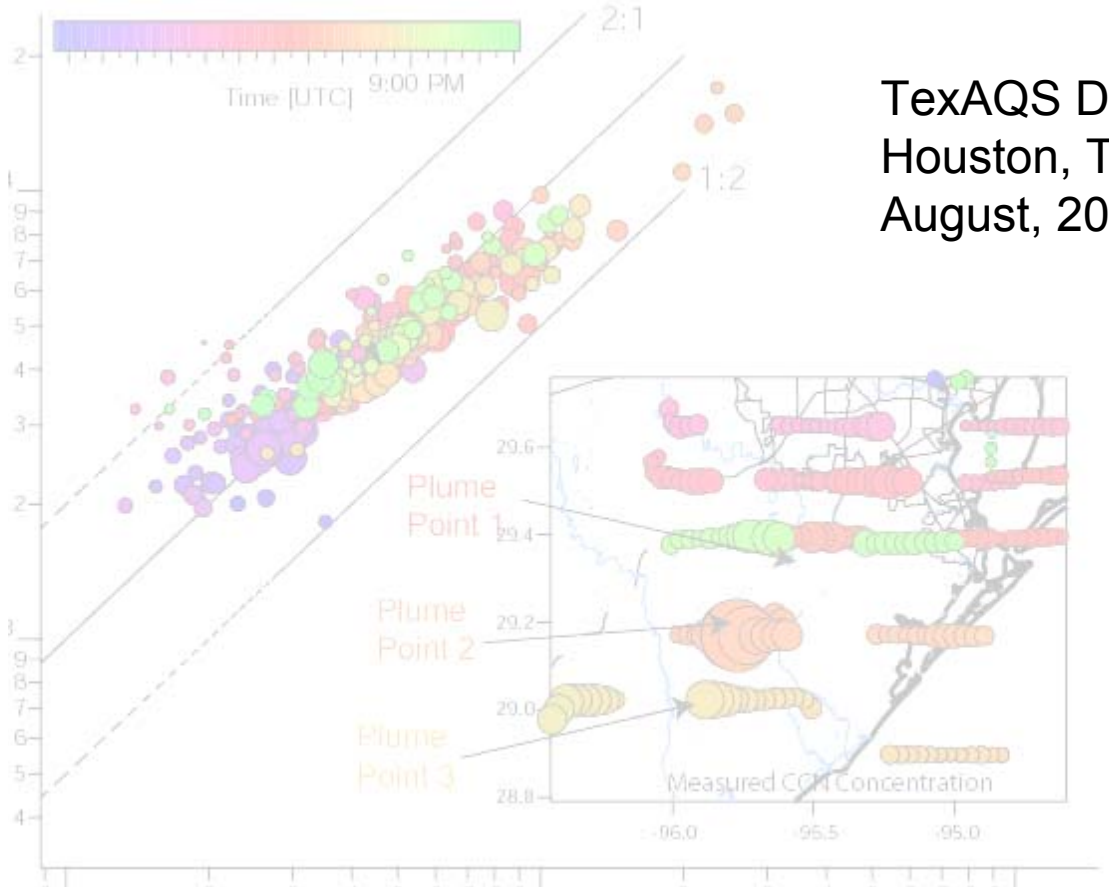
$$d_{p,crit} = \frac{27}{256} s^2 \left(\frac{\rho_w RT}{M_w \sigma}\right)^3 \left(\frac{\rho_s}{M_s}\frac{M_w}{\rho_w} \upsilon_s \varepsilon_s\right)^{1/3}$$



Sample Size Distribution from TexAQS

Does the predicted concentration match what we measure?

CCN Closure: Comparing Observations with Predictions from Köhler Theory

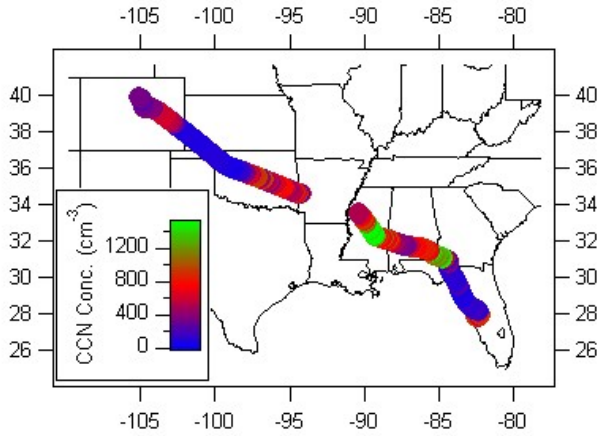


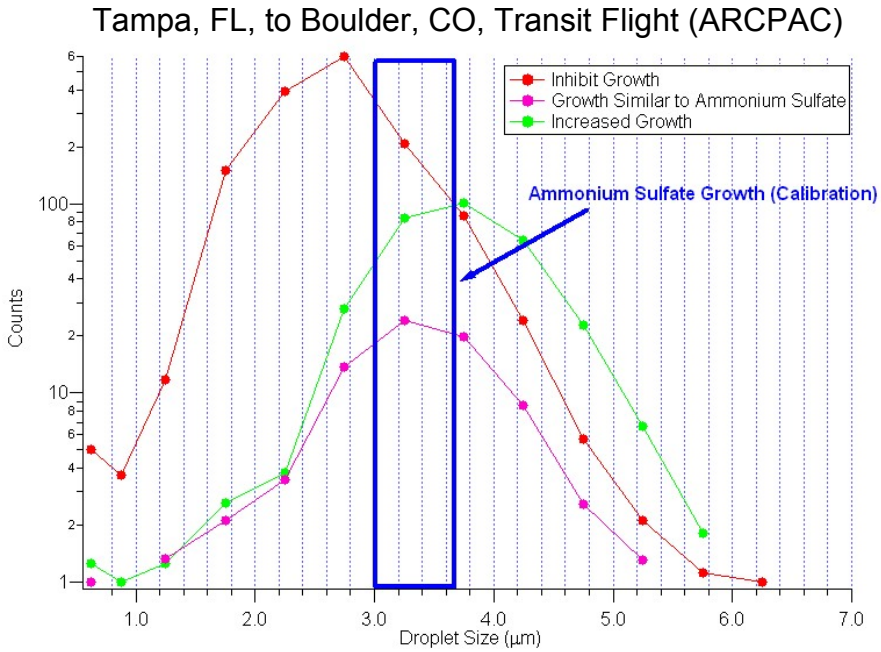
TexAQS Data
Houston, TX
August, 2006

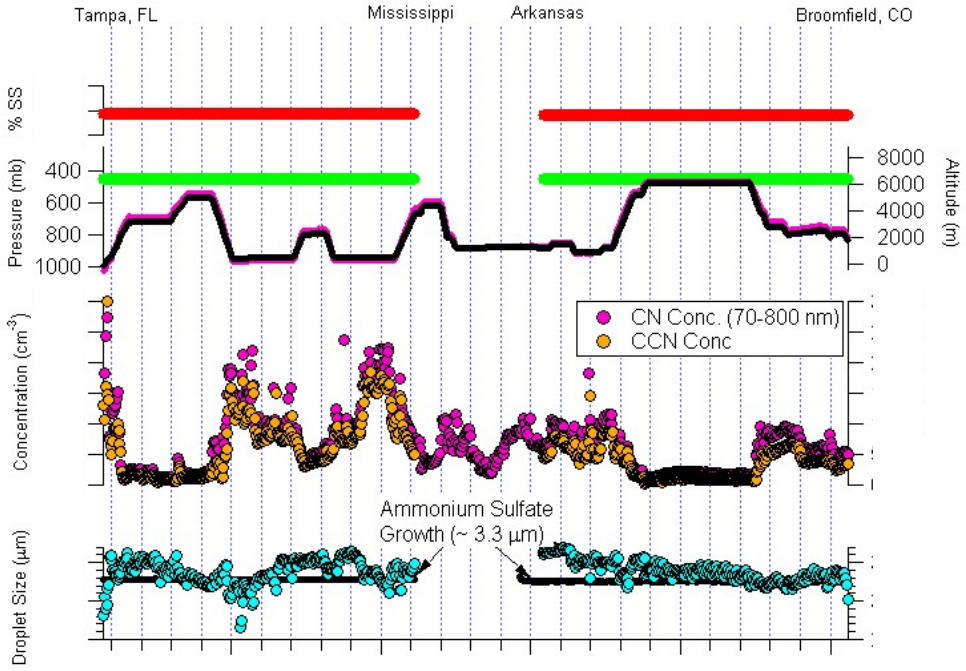
Asa-Awuku et al., *in prep.*

Characterizing Droplet Growth Kinetics

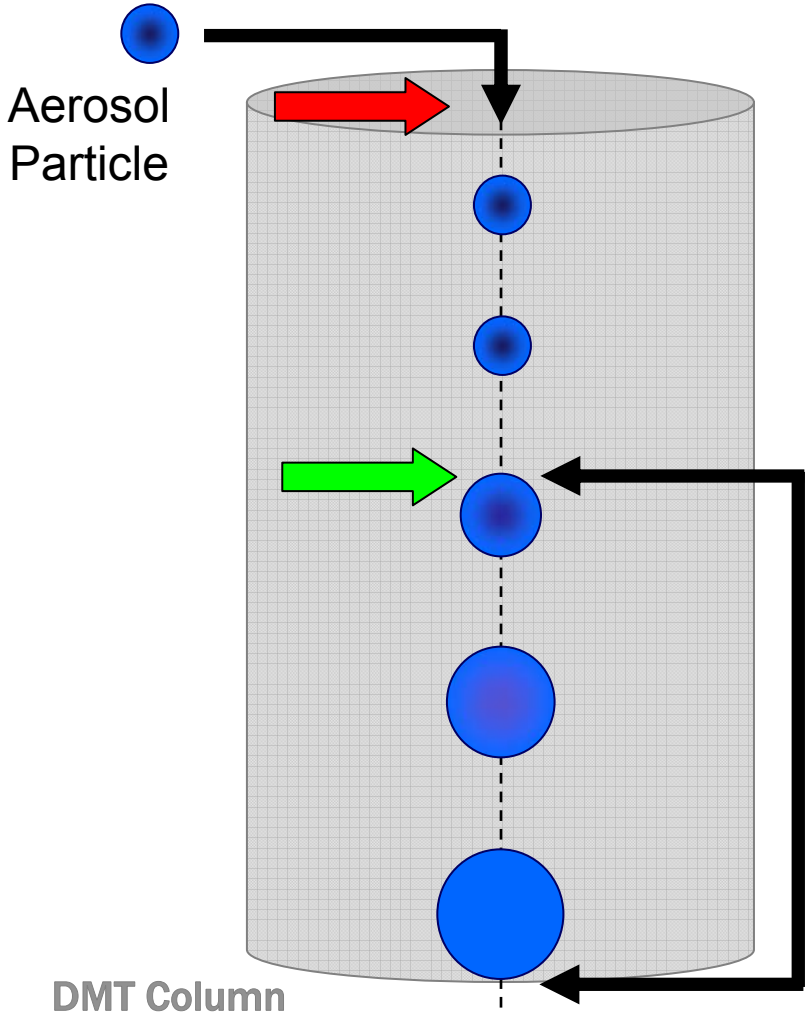
- As a first step, evaluate droplet growth with respect to ammonium sulfate calibration aerosol
- The next step will be to model the aerosol residence time and apply the droplet growth equation to infer the water uptake coefficient

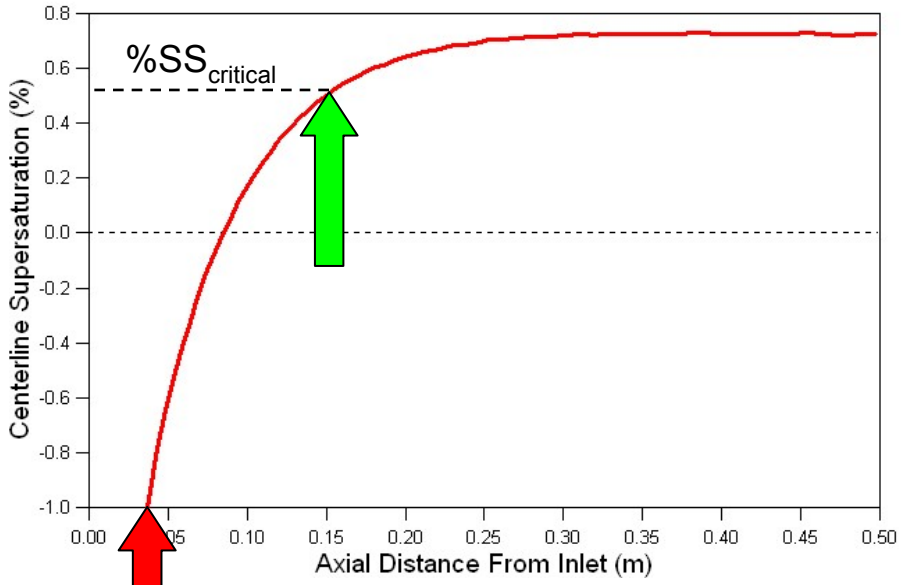






Characterizing Droplet Growth Kinetics



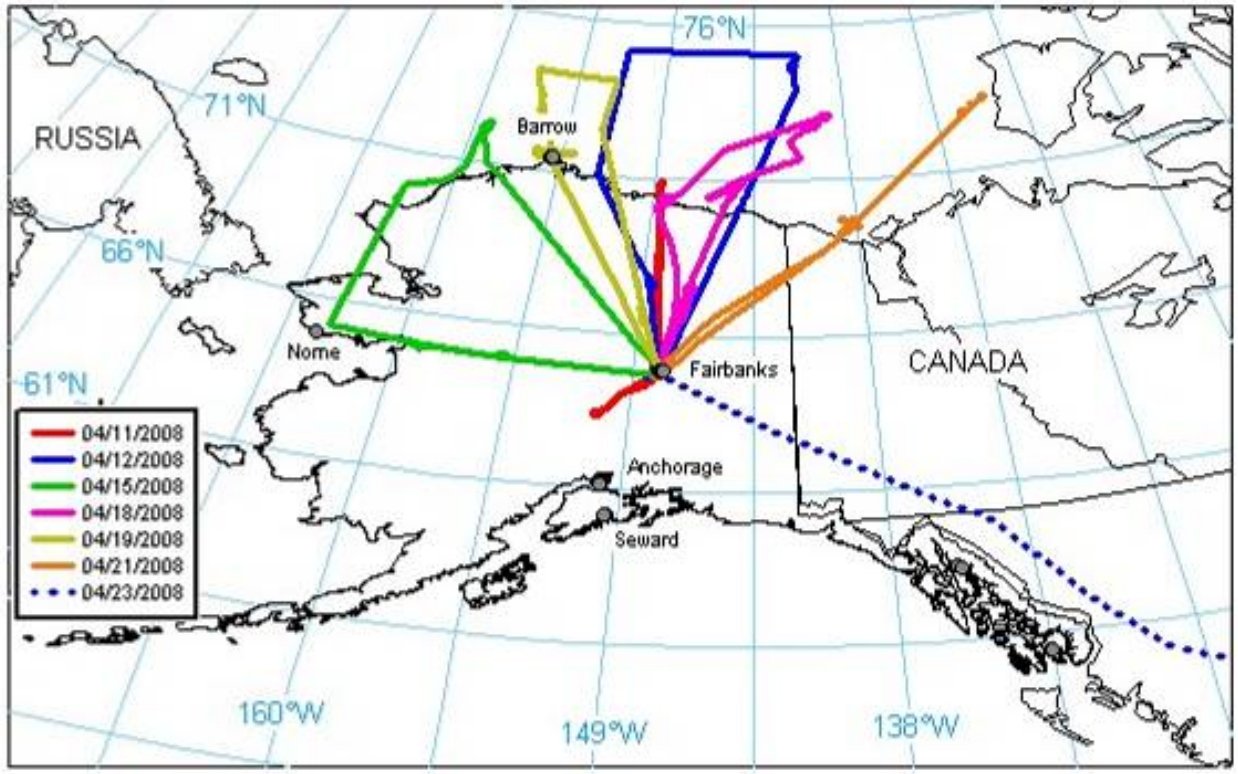


$$\frac{\Delta D_p}{\Delta t} \cong \frac{1}{D_p} \cdot \frac{\left(S_\infty - S_{eq}\right)}{\frac{\rho_w R T_\infty}{4 p_w^\circ(T_\infty) D_v' M_w} + \frac{\Delta H_v \rho_w}{4 k_a' T_\infty}\left(\frac{\Delta H_v M_w}{T_\infty R} - 1\right)}$$

$$D_v' = \frac{D_v}{1 + \frac{2 D_v}{\gamma_c D_p}\left(\frac{2\pi M_w}{RT}\right)^{1/2}} \qquad k_a' = \frac{k_a}{1 + \frac{2 k_a}{\gamma_T D_p \rho \hat{c}_p}\left(\frac{2\pi M_a}{RT_a}\right)^{1/2}}$$

Summary of ARCPAC Data

- FL to CO Transit (3/29) – **POWER FAILURE BETWEEN 17:46 AND 18:38 UTC**
- CO Flight (4/1) – **LEAK**
- CO to AK Transit (4/3) – **INSTRUMENT IN DRYING MODE**
- AK Flight #1 (4/11) – **POWER FAILURE AFTER 20:46 UTC**
- AK Flight #2 (4/12)
- AK Flight #3 (4/15)
- AK Flight #4 (4/18)
- AK Flight #5 (4/19)
- AK Flight #6 (4/21)
- AK to CO Transit (4/23)

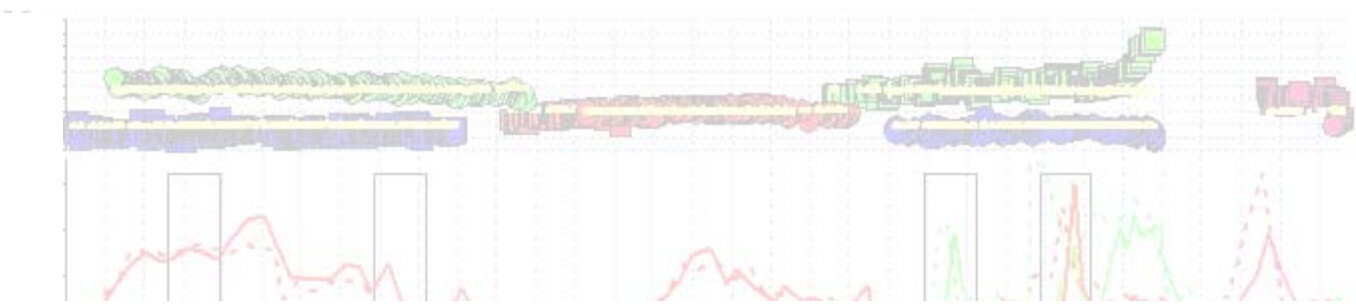


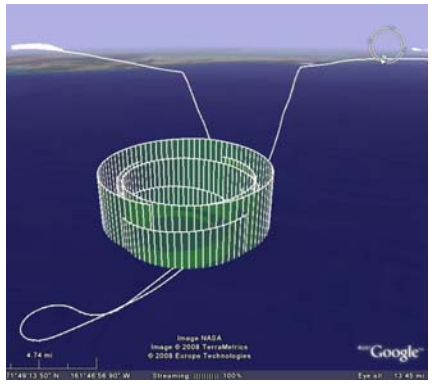
Arctic Haze Layers

from NASA DC-8 (4/12)

Arctic Haze Layers

4/15/2008: 2nd Cone top profile: 00:23-00:40 Ascent, 00:40-00:59 Descent

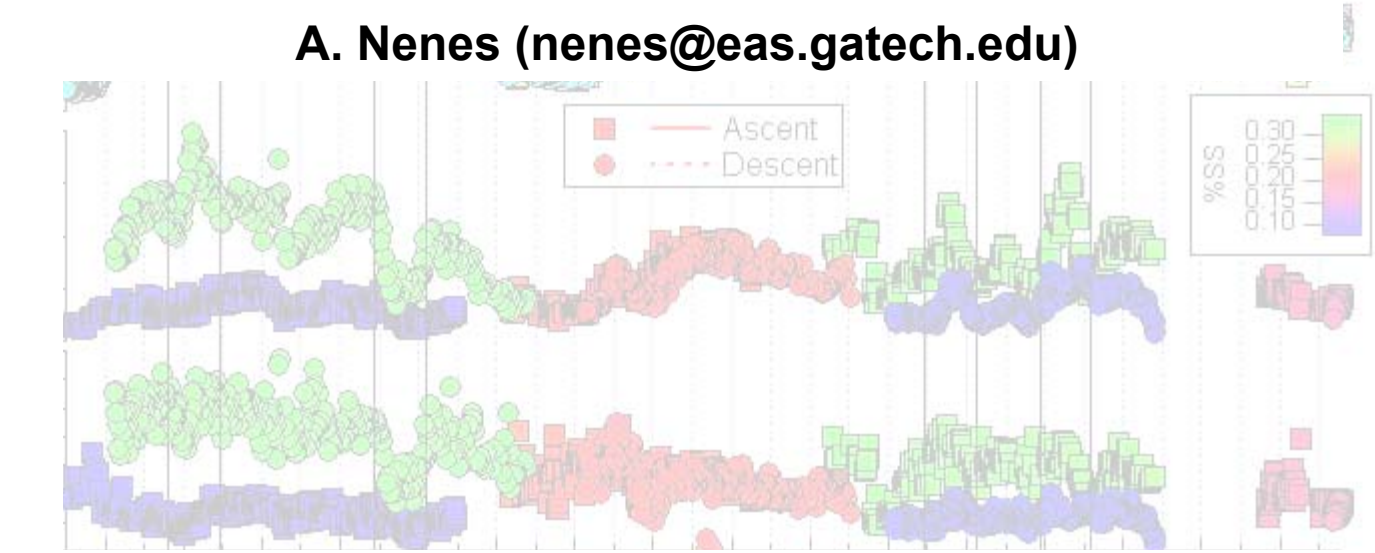




Preliminary CCN Data Omitted Until Finalized

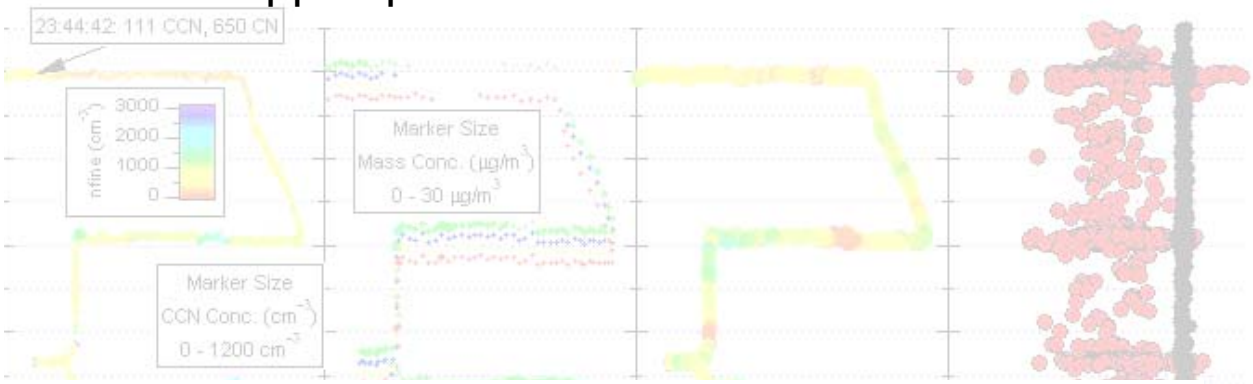
Contact the PI for Assistance

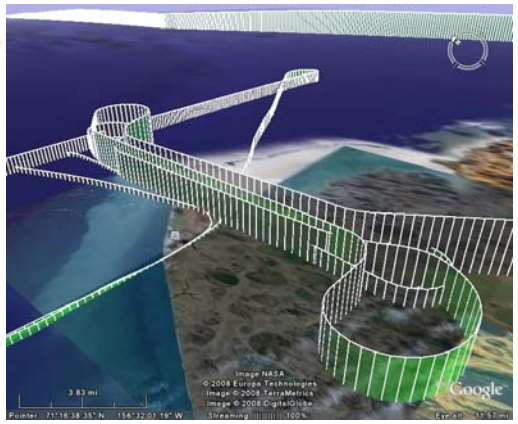
A. Nenes (nenes@eas.gatech.edu)



Arctic Haze Layers

4/19/2008: Stepped profile Over Barrow: 23:30-00:30 Descent

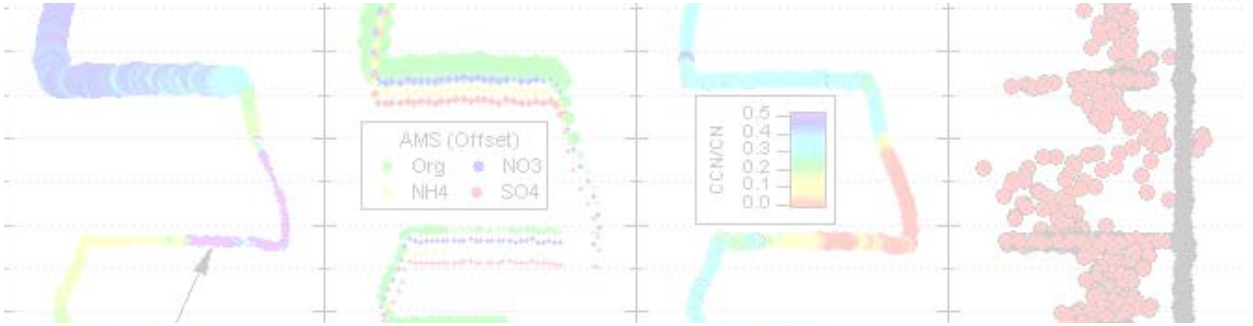




Preliminary CCN Data Omitted Until Finalized

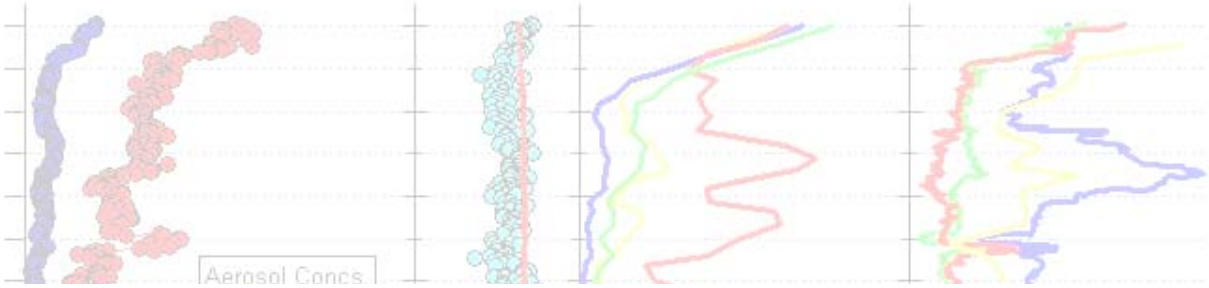
Contact the PI for Assistance

A. Nenes (nenes@eas.gatech.edu)



Arctic Haze Layers

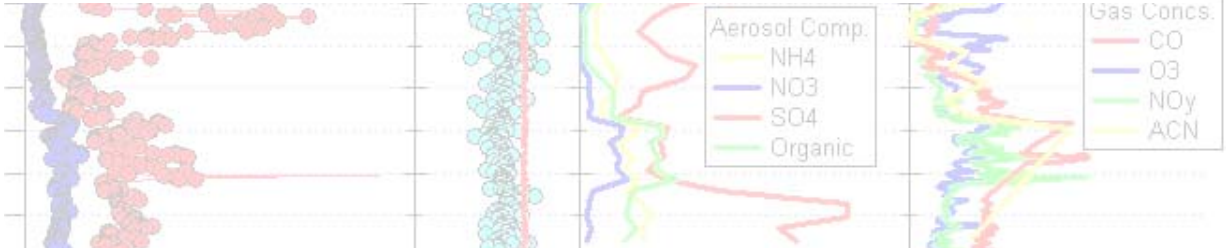
4/21/2008: Descending Profile Near Coast: 23:57-00:08

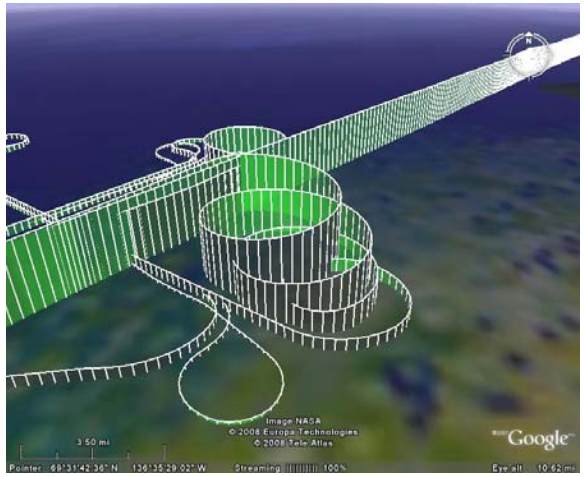


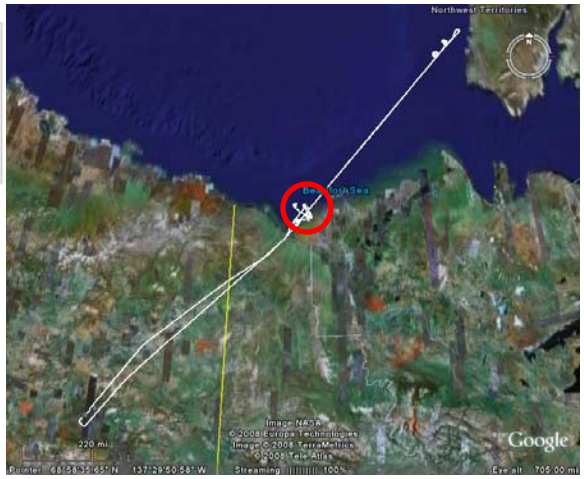
Preliminary CCN Data Omitted Until Finalized

Contact the PI for Assistance

A. Nenes (nenes@eas.gatech.edu)







Scientific Questions

- Compare CCN Closure & Growth Kinetics:
  - **Haze Layer vs. Background**
- Do organics contribute to soluble mass?
  (*Models currently neglect organic contribution to CCN.*)
- Do organics depress surface tension and/or lower growth kinetics?
- How can we link inferred CCN properties to observed cloud properties?

Acknowledgements

- Thanos Nenes and the GA Tech Aerosol-Cloud Research Group
- Greg Huey, Dave Tanner, and Mark Lord for Integration Assistance
- NOAA Folks: Chuck Brock, Tom Ryerson, Jeff Peischl, Sara Lance, Julie Cozic, Roya Bahreini, Ann Middlebrook, Joost deGouw, Carsten Warneke, Ken Aiken
- GCEP: Jeff Gaffney, Nancy Marley, and Milton Constantin

Funding: RHM: DOE GCEP GREF, GA Tech President's Fellowship; AN: NOAA Grant, NSF CAREER

Questions?